28. The semiconductor device according to claim 27, further comprising another neighboring film, adjacent a side of the copper or platinum film opposite a side thereof having said neighboring film adjacent thereto, said another neighboring film being made of a material selected from the group consisting of rhodium, ruthenium, iridium, osmium and platinum.

29. The semiconductor device according to claim 28, wherein both the neighboring film and the another neighboring film are films formed by physical vapor deposition.--

REMARKS

Applicants have amended their title, such that the new title is the title suggested by the Examiner in Item 4 on page 3 of the Office Action mailed July 10, 2000. In view of this new title, the requirement for a new title has been satisfied.

Applicants have amended their claims in order to further clarify the definition of the present invention. Specifically, claim 7 has been canceled without prejudice or disclaimer. In view of the canceling of claim 7, it is respectfully submitted that the rejection of claim 7 under 35 USC 102(e), as anticipated by the teachings of Woo, et al., set forth in Item 6 on pages 3 and 4 of the Office Action mailed July 10, 2000, is moot.

In addition, Applicants have added new claims 9-29 to the application. Of these newly added claims, claims 9 and 27 are independent claims, and each defines a semiconductor device.

Claim 9 recites that the semiconductor device has a layered interconnection structure including a copper or platinum film formed overlying a surface of a semiconductor substrate, this interconnection structure including the copper or platinum film and a neighboring film adjacent the copper or platinum film, the neighboring film made of a material selected from a first group of materials when the layered interconnection structure includes a copper film, and is made of a material selected from a second group when the layered interconnection structure includes a platinum film, at least one of (a) the copper or platinum film and (b) the neighboring film is a film made by physical vapor deposition, and wherein the device further comprises a diffusion barrier layer, with the neighboring film being sandwiched between the copper of platinum film and the diffusion barrier layer. Claim 10, dependent on claim 9, recites that the neighboring film and diffusion barrier layer respectively are in contact with the copper or platinum film and with the neighboring film. Claims 11 and 12, dependent respectively on claims 9 and 11, respectively recites that the layered interconnection structure includes the platinum film; and recites that the diffusion barrier layer is at least one film made of specified materials. Claims 13 and 14, each dependent on claim 11, respectively recites that the platinum film is a film formed by physical vapor deposition, and recites that the neighboring film is a film formed by physical vapor deposition. Claim 15, dependent on claim 11, recites that both the neighboring film

and the platinum film are films formed by physical vapor deposition.

Claim 16, dependent on claim 9, recites that the layered interconnection structure includes the copper film; and claims 17-20 correspond respectively to claims 12-15, but are directed to that aspect of the present invention wherein the copper film is utilized, each of claims 17-20 being dependent on claim 16. Claims 21 and 22, each dependent on claim 9, respectively recites that the neighboring film is in contact with the copper or platinum film; and recites further structure of an insulating film overlying the layered interconnection structure and having a contact hole therethrough exposing the layered interconnection structure, with the hole having an electrically conductive plug therethrough, in electrical contact with the layered interconnection structure, and with another layered interconnection structure on the insulating film and electrically contacting the plug. Claims 23 and 24, each dependent on claim 22, respectively recites that the plug is a plug formed by physical vapor deposition, and further defines the structure of the another layered interconnection structure, as including a copper or platinum film and a further neighboring film between the plug and the copper or platinum film, material of this further neighboring film being defined. Claim 25, dependent on claim 24, defines the structure as including another diffusion barrier layer between the plug and the further neighboring film; and claim 26

recites the same subject matter as in claim 12, but is dependent on claim 25.

New independent claim 27 defines a semiconductor device having a layered interconnection structure including a copper film formed overlying a surface of a semiconductor substrate, this structure including the copper film and a neighboring film adjacent the copper film, the neighboring film being made of a specified material, and with at least one of the copper film and the neighboring film being a film made by physical vapor deposition. Claims 28 and 29, dependent respectively on claims 27 and 28, respectively recites that the device includes another neighboring film, made of a specified material; and recites that both the neighboring film and another neighboring film are formed by physical vapor deposition.

In connection with the newly added claims, note, for example, pages 3-5 of Applicants' specification, together with Fig. 7 and the description on pages 16-18, and Fig. 8 and pages 19-21, for example, of Applicants' specification.

Applicants respectfully submit that all of the claims in the application patentably distinguish over the teachings of the references applied by the Examiner in rejecting the claims formerly in the application, that is, the teachings of the U.S. patents to Woo, et al., No. 6,054,331, to Hussein, et al., No. 6,020,266, and to Schacham-Diamand, et al., No. 5,824,599, and IBM Technical Disclosure Bulletin, vol. 35 no. 1B (June 1992), pages 214 and 215, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that these references as applied by the Examiner would have neither disclosed nor would have suggested such a semiconductor device as in the present claims, including, inter alia, wherein the device has layered interconnection structure including a copper film interconnect and a diffusion barrier formed in contact with this interconnect, this diffusion barrier being formed of a ruthenium film and wherein the copper film has a layered structure including a copper film formed through sputtering or physical vapor deposition, and a copper film formed through plating or chemical vapor deposition. See claims 1-3.

In addition, it is respectfully submitted that the applied references would have neither taught nor would have suggested such a semiconductor device as in the present claims, having a copper film interconnect and a plug formed in contact with the copper film interconnect, wherein the plug is formed of at least one film selected from the group consisting of a rhodium film, a ruthenium film, an iridium film, an osmium film and a platinum film, with at least one of the copper film interconnect and the plug containing a layer formed by physical vapor deposition. See claims 4 and 5.

Furthermore, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such a semiconductor device as in the present claims, having the copper film interconnect, the diffusion barrier and the plug, wherein at least one of the copper film interconnect and the plug contains a layer formed through physical vapor deposition. See claim 5.

Moreover, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such a semiconductor device as in the present claims, having the recited copper film interconnect, first and second diffusion barriers and plug, and wherein the first diffusion barrier and the plug are formed of ruthenium films and the second diffusion barrier is formed of a titanium nitride film, and with at least one of the copper film interconnect and the first barrier layer being a film formed through sputtering. See claim 6.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such semiconductor device as in the present claims, having the layered interconnection structure including a copper or platinum film, with the layered interconnection structure including a neighboring film adjacent the copper or platinum film, the neighboring film being made of the material selected from a first group consisting of rhodium, ruthenium, iridium, osmium and platinum when the layered interconnection structure includes a copper film, and the neighboring film being made of a material selected from a second group consisting of rhodium, ruthenium, iridium and osmium when the layered interconnection structure includes a platinum film, at least one of (a) the copper or platinum film and (b) the neighboring film being a film made by physical vapor deposition, the structure further comprising a diffusion barrier layer, the neighboring film being

sandwiched between the copper or platinum film and the diffusion barrier layer. See claim 9.

Furthermore, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such a semiconductor device as in the present claims, having a layered interconnection structure including a copper film overlying a surface of a semiconductor substrate, this structure including the copper film and a neighboring film adjacent the copper film, with the neighboring film made of material selected from a group consisting of rhodium, ruthenium, iridium, osmium and platinum, at least one of the copper film and the neighboring film being a film made by physical vapor deposition. See claim 27.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested the additional aspects of the present invention as recited in the dependent claims, including (but not limited to) wherein the layered interconnection structure includes the platinum film (see claim 11) or the copper film (see claims 16 and 27); and/or wherein the platinum or copper film is formed by physical vapor deposition (see claims 13 and 18), or wherein the neighboring film is formed by physical vapor deposition (see claims 14 and 19), or wherein both the neighboring and platinum or copper films are formed by physical vapor deposition (see claims 15 and 20).

Furthermore, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such a semiconductor device as in the present claims, having the insulating film and a via, the via connecting layered interconnection structures at different levels, as in claims 22-26.

The present invention is directed to a semiconductor device having layered interconnect structure, which has satisfactory electromigration resistance and therefore avoids the problem of voids and interconnect breakdowns.

Large-scale-integration semiconductor devices with fine patterns receive a high-density current, in which atoms move owing to electron streams flowing therein and to the heat that is generated by the flow of electrons, thereby causing voids and interconnect breakdowns. That is, due to electromigration, voids and interconnect breakdowns occur. Copper films, having a relatively high melting point as compared to that of, e.g., aluminum, are expected to have good electromigration resistance. However, layered interconnect structures utilizing a diffusion barrier of, for example, titanium nitride, tungsten or tantalum, kept in contact with the copper film, do not have a satisfactory electromigration resistance, and therefore pose problems in connection with voids and interconnect breakdowns.

Against this background, Applicants provide structure of a layered interconnect which avoids voids and interconnect breakdowns, providing a reliable semiconductor device. Applicants have found that, in a layered interconnect

structure utilizing a diffusion barrier of a material as set forth previously, which is kept in contact with a copper film, significant differences between the material of the diffusion barrier material and copper, in the length of the sides of the unit cells thereof, bring about a disordered atomic configuration at the interface therebetween, promoting copper movement that results in the voids and interconnect breakdowns. See the paragraph bridging pages 2 and 3 of Applicants' specification. Utilizing this information, Applicants provide a layered interconnect structure comprising a conductor film and a neighboring film wherein the difference in a length of the sides of the unit cell between the adjacent layers is reduced, so as to avoid the electromigration and resulting voids and interconnect breakdowns. Specifically, Applicants have found that by utilizing a neighboring film, in contact with the copper film, made of a material selected from the group consisting of rhodium, ruthenium, iridium, osmium and platinum, the voids and interconnect breakdowns due to electromigration are avoided. Moreover, when utilizing a platinum film, Applicants have found that by utilizing a neighboring film of a material selected from the group consisting of rhodium, ruthenium, iridium and osium, problems in connection with electromigration and resulting voids and interconnect breakdowns can be avoided.

Moreover, by providing one of the layers, of the copper or platinum or of the neighboring layer (including a plug layer) by physical vapor deposition, highly adhesive structure can be achieved, and electromigration is avoided.

It is respectfully submitted that the electromigration is a different phenomenon than normal diffusion between, for example, the interconnect and the silicon substrate. Moreover, it is respectfully submitted that the interconnect and/or diffusion barrier formed by chemical vapor deposition or plating cannot prevent electromigration. On the other hand, according to the present invention, utilizing physical vapor deposition (for example, sputtering), the electromigration can be avoided, to avoid voids and interconnect breakdowns, while achieving good adhesiveness between the various layers.

Claim 7, which was rejected as being anticipated by the teachings of Woo, et al., has been canceled without prejudice or disclaimer. Accordingly, the rejection as set forth in Item 6 bridging pages 3 and 4 of the Office Action mailed July 10, 2000, is moot.

In connection with claims 1-3, Hussein, et al. discloses fabrication of via plugs and metal lines in interconnect systems, the structure including a barrier layer formed onto a surface of a substrate that has at least one via. A conductive layer is formed onto the barrier layer, and a photoresist layer is formed onto the conductive layer. The photoresist layer is patterned. A metal via plug is formed onto the at least one via, and a metal line is formed onto the metal via plug. The layer of photoresist is removed, and the conductive layer, not covered by the metal line, is also removed. See column 2, lines 14-22. Note also column 3, lines 18 and 19, disclosing that appropriate conductive

materials for the barrier layer 5 (see Fig. 1) is titanium nitride or tantalum; and that various processes may be used to apply the conductive layer 7 to the barrier layer 5, one such process being sputtering. See column 3, lines 18, 19 and 55-58. The metal lines and via plugs can be formed using an electroplating bath of copper, for example. See column 4, lines 34-52.

It is respectfully submitted that Hussein, et al. discloses forming the plug by an electroplating process. This patent would have neither taught nor would have suggested such plug as in the present claims, having been formed by physical vapor deposition, or advantages achieved thereby as discussed in the foregoing. In addition, it is respectfully submitted that the teachings of this reference would have neither disclosed nor would have suggested the neighboring layer to the copper as in the present claims, or advantages achieved with the neighboring layer and by utilizing physical vapor deposition, including avoidance of electromigration and advantages achieved thereby as discussed in the foregoing.

The IBM Technical Disclosure Bulletin describes a diffusion barrier between copper and silicon, such diffusion barrier being made of rhenium.

It is emphasized that the IBM Technical Disclosure Bulletin describes rhenium as a diffusion barrier between copper and silicon. Such disclosure, either alone or in combination with the teachings of Hussein, et al., would have neither disclosed nor would have suggested the presently claimed structure, including the copper, neighboring film and

diffusion barrier layer, much less layers of the specific material or layers formed by physical vapor deposition, and advantages achieved thereby, as discussed in the foregoing.

The contention by the Examiner that the IBM Technical Disclosure Bulletin "does teach that ruthenium (as well as rhenium, osmium and iridium) is an exceptional barrier against the diffusion of copper" is noted. It must be emphasized that in view of the disclosure of, e.g., rhenium as a barrier against diffusion, one of ordinary skill in the art involved in connection with Hussein, et al. would not have utilized the rhenium layer in addition to the barrier layer of Hussein, et al.

Moreover, it is emphasized that the IBM Technical Disclosure Bulletin describes the rhenium and other materials as a barrier against diffusion. It is respectfully submitted that this diffusion is different from the electromigration as addressed by the present invention. It is respectfully submitted that the combined teachings of Hussein, et al. and of the IBM Technical Disclosure Bulletin would have neither taught nor would have suggested the presently claimed invention, including the various layers, and advantages thereof of avoiding electromigration.

Schacham-Diamand, et al. discloses a technique for fabricating copper interconnects by electroless metallization wherein a copper catalytic layer is utilized to initiate the autocatalytic process of electroless deposition, and a protective layer is utilized to protect the catalytic surface until, e.g., the substrate (wafer) is subjected to the

electroless deposition technique. See column 2, lines 50-55. Note also the paragraph bridging columns 2 and 3, and first two paragraphs in column 3, of Schacham-Diamand, et al.

The structure formed in Schacham-Diamand, et al. includes an electroless copper layer on a catalytic copper seed layer conformally blanket deposited in a vacuum over a barrier layer. The barrier layer is a titanium nitride or tantalum barrier layer. Even assuming, arguendo, that the teachings of Schacham-Diamand, et al. and of the IBM Technical Disclosure Bulletin were properly combinable, such combined teachings would, at best, have taught use of rhenium, etc., as the barrier layer. Such disclosure would have neither taught nor would have suggested the presently claimed subject matter, including the diffusion barrier layer together with the neighboring layer adjacent the copper or platinum, or wherein various layers are layers provided by physical vapor deposition, and advantages achieved thereby, as discussed in the foregoing.

Woo, et al. discloses a technique for depositing a platinum film, which is used as a bottom electrode of a capacitor in a high density DRAM and in a non-volatile memory cell including a FRAM memory cell. A functional intermediate layer, such as an insulating layer, a conductive plug layer, a diffusion barrier layer, or an adhesive or glue layer, is formed between the platinum film and the substrate. Various materials are described as being usable as the functional intermediate film, in the second full paragraph of column 4 of this patent. These materials include a functional

intermediate film used for adhesion or glue, including TiN, W, Ta, Ti, Sn, Ru, In, Ir, Os, Rh and silicide compound. See, for example, column 4, lines 48-51.

Note that Woo, et al. discloses use of a platinum film. The disclosure of this patent, either alone or in combination with the teachings of the other references as applied by the Examiner, would have neither disclosed nor would have suggested that aspect of the present invention utilizing a copper film.

Furthermore, it is respectfully submitted that the teachings of Schacham-Diamand, et al., the IBM Technical Disclosure Bulletin and Woo, et al. would have neither taught nor would have suggested the other aspects of the present invention, including the use of layers formed by physical vapor deposition, and/or both the neighboring film and diffusion barrier layer, and advantages achieved thereby in avoiding electromigration and the resulting voids and interconnect breakdown.

Moreover, note that various of the claims recite a copper film formed of sub-films respectively provided through, for example, sputtering and through plating (or, for example, through physical vapor deposition and through chemical vapor deposition). It is respectfully submitted that the applied references do not disclose, nor would have suggested, structure including layers of a same material formed by different procedures, which provide, in effect, different layers of a same material. Clearly, the teachings of the applied prior art do not disclose, nor would have suggested,

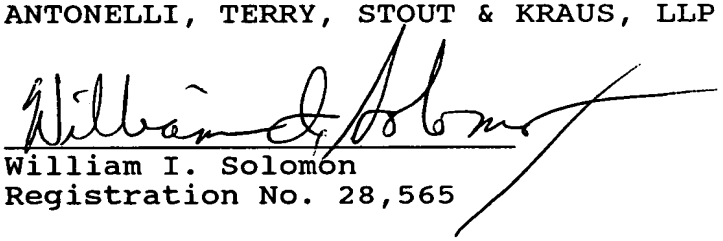
this aspect of the present invention, the advantages of avoiding electromigration when providing, e.g., a part of the total thickness of copper by physical vapor deposition, including, e.g., sputtering. Note claims 1-3.

In view of the foregoing comments and amendments to the claims, reconsideration and allowance of all claims remaining in the application are respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 CFR § 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No. 01-2135 (Case No. 501.36931X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

ANTONELLI, TERRY, STOUT & KRAUS, LLP



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WIS/slk

27. (Twice Amended) A semiconductor device having a layered interconnection structure including a copper film formed overlying a surface of a semiconductor substrate, wherein the layered interconnection structure includes the copper film and a neighboring film adjacent the copper film, the neighboring film [being made of] <u>including</u> a material selected from a group consisting of rhodium, ruthenium, iridium, osmium and platinum, at least one of (a) the copper film and (b) the neighboring film being a film made by physical vapor deposition, wherein the neighboring film substantially prevents voids due to electromigration of copper of the copper film.